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Efficacy of Left Atrial Radiofrequency Surgical Ablation in Patients with Atrial Fibrillation and Concomitant Cardiac Surgical Pathology

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SOUHRN

Cíl: Cílem studie bylo zjistit proveditelnost chirurgické ablace levé síně u pacientů s fibrilací síní a souběžnými kardiovaskulárními onemocněními.
Soubor a metodika: Experiment byl proveden ve Vědecko-praktickém lékařském centru dětské kardiologie a kardiochirurgie, Klinika pro dospělé (Kyjev, Ukrajina, 2024). Studie se zúčastnilo celkem 69 pacientů, kteří podstoupili chirurgickou léčbu fibrilace síní a souběžných kardiovaskulárních onemocnění.
Výsledky: Bylo zjištěno, že po provedení chirurgické ablace levé síně zaměřené na ložisko fibrilace síní byl sinusový uzel hlavním rytmogenerátorem u 45 pacientů (65 % z celkového počtu). U 18 pacientů (26 %) přetrvávaly poruchy rytmu ve formě fibrilace síní, 4 pacienti (6 %) měli síňový flutter a u 2 pacientů (3 %) byl diagnostikován flutter levé síně. Mezi účastníky studie mělo téměř 61 % (42 pacientů) dlouhotrvající formu fibrilace síní a průměrnou velikost levé síně 5,2 ± 0,6 cm, což významně zhoršovalo výsledky chirurgické léčby. Účinnost radiofrekvenční ablace byla nižší u pacientů s tradičními prediktory neúspěchu, konkrétně u pacientů starších 70 let, s velikostí levé síně 5 cm nebo více, s fibrilací síní trvající déle než pět let a u pacientů s perzistující a dlouhotrvající fibrilací síní.
Závěr: Studie dospěla k závěru, že samotná radiofrekvenční ablace levé síně byla podmíněně úspěšná u pacientů s kratší dobou trvání fibrilace síní a menší velikostí levé síně.

Keywords:
Cardiac arrhythmias
Cardiovascular diseases
Thoracoscopic access
Hybrid techniques
Cox-Maze IV surgery

ABSTRACT

Aim: The aim of the study was to determine the feasibility of left atrial surgical ablation in patients with atrial fibrillation and concomitant cardiovascular diseases.
Methods: The experiment was conducted at the Scientific and Practical Medical Centre of Paediatric Cardiology and Cardiac Surgery, Adult Clinic (Kyiv, Ukraine, 2024). A total of 69 patients who underwent surgical treatment for atrial fibrillation and concomitant cardiovascular disease took part in the study.
Results: It was found that after the procedure of left atrial surgical ablation of the atrial fibrillation focus, the sinus node was the rhythm driver in 45 patients (65% of all). In 18 patients (26%), rhythm disturbances remained in the form of atrial fibrillation, 4 patients (6%) had atrial flutter, and 2 patients (3%) had left atrial flutter. Among the study participants, almost 61% (42 patients) had a long-standing form of atrial fibrillation and an average left atrial size of 5.2 ± 0.6 cm, which significantly worsened the results of surgical treatment. The efficacy of radiofrequency ablation was lower in patients with traditional predictors of failure, namely, patients over 70 years of age, left atrial size of 5 cm or more, atrial fibrillation duration of more than 5 years, and persistent and long-standing atrial fibrillation.
Conclusions: The study concluded that radiofrequency ablation of the left atrium alone was conditionally successful in patients with shorter duration of atrial fibrillation and smaller left atrial size.

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Introduction

Atrial fibrillation (AF) is a common cardiac rhythm disorder diagnosed in 33.5 million people worldwide.[1] In the population of European countries, this pathology occurs with a frequency of 3% starting from the age of 20. It affects mainly Caucasian men.[2] In Asians, the prevalence of AF is less than 1%. At the same time, Sagris et al.[1] note that in 10 years, the prevalence of atrial fibrillation among European residents will double. Aldaas et al.[2] and Al-Ezzi et al.[3] found that the risk factors for AF are hypertension, obesity, coronary heart disease, and smoking. Predictors of the progression of persistent atrial fibrillation in patients awaiting ablation are: hypertension, advanced age, and ischaemic attacks. This cardiac rhythm disorder can be a complication of any pathology of the valvular heart apparatus. For example, AF is most commonly diagnosed in patients with mitral valve damage due to rheumatic diseases. In people with mild to moderate aortic stenosis, the prevalence of AF is 10%, and in severe stenosis – 33.7%. In isolated mitral insufficiency, AF is detected in 15% of cases; in isolated mitral stenosis – in 29% of cases; in a combination of stenosis and regurgitation – in 52%. The incidence of atrial fibrillation is 65–75% in the case of a combination of mitral and tricuspid valve pathology.[2]

Ren et al.[4] and Volgman et al.[5] note that patients with AF have a fourfold higher risk of stroke and heart attack. AF also increases the risk of cognitive impairment and anxiety. Scientists Ferro et al.,[6] Cheng et al.,[7] and Skybchyk et al.[8] note that AF mainly affects people aged 70–80 years, with a frequency of 10–20%. From 2010 to 2020, many studies were conducted to investigate the features of atrial fibrillation and the effects of ablation in AF in the elderly. At the same time, more attention should be paid to strategies for developing effective treatments and prevention of AF in younger people. Leszto et al.[9] studied the relationship between the type of diet and the effectiveness of prevention and treatment of atrial fibrillation; the possibilities of non-drug treatment of cardiac pathology were assessed.

Since 2000, catheter-based and surgical ablation for AF has transitioned from primarily diagnostic measures to well-established therapeutic interventions for managing heart disease. Surgical ablation techniques have diversified, encompassing standard, minimally invasive, and hybrid approaches. Among these, radiofrequency ablation has demonstrated considerable success, particularly in enhancing patients' quality of life and postoperative survival.[10,11] Transcatheter radiofrequency ablation has proven effective in reducing recurrence rates, especially in symptomatic AF. However, selecting the optimal therapeutic approach remains a significant challenge, as the severity and progression of AF are closely influenced by various comorbidities. For instance, Peigh et al.[12] note that permanent AF is associated with a significantly higher risk of thromboembolism and mortality compared to paroxysmal AF. Additionally, paroxysmal AF has been linked to a higher prevalence of depressive disorders, further emphasizing the complex interplay between AF types and patient well-being.[4]

However, the exact mechanism of psychological disorders in cardiac pathology is still under investigation. Thus, there are currently many controversial issues when choosing the optimal type of surgery, access, indications, and contraindications for atrial fibrillation. The aim of the present study was to evaluate the effectiveness of left atrial surgical ablation of atrial fibrillation in patients with concomitant cardiac surgery pathology. The following objectives were set: determining the prevalence of atrial fibrillation, its types and mechanisms of development; analysing the risk factors for AF and ways to prevent this pathology; studying the types of possible surgical interventions for AF; investigating the predictors of surgical ablation failure in AF.

Materials and methods

The present open-label retrospective study was conducted in 2024 at the Scientific and Practical Medical Centre for Paediatric Cardiology and Cardiac Surgery, Clinic for Adults, Ministry of Health of Ukraine, Kyiv. The trial involved 69 patients who underwent surgical treatment for atrial fibrillation and related pathology. **Table 1** shows the main clinical and morphological characteristics of the patients who participated in the study. Thirty-seven patients were male and 32 were female, which made up 54% and 46%, respectively. The average age of the study group was 63 years. Among the parameters of transthoracic echocardiography, the mean ejection fraction and left atrial dimensions were evaluated. The diameter of the left atrium (2D-guided linear LA measurement) was determined by cardiac ultrasound. Taking into account the patients' symptoms and objective examination data, patients with heart failure were classified according to *the New York Heart Association* (NYHA) scale. Thirty-four (49%) patients had severe symptoms of heart failure, so they were classified as NYHA class III.

The analysis was conducted using SPSS version 27.0 (IBM Corp., Armonk, NY, USA), ensuring accurate statistical computations and enhancing the reproducibility of the study. Continuous variables, such as left atrial diameter and ejection fraction, were analysed using Student's t-test, while categorical variables, including NYHA class and severe heart failure symptoms, were analysed using chi-square tests. Logistic regression was employed to assess associations between clinical variables (e.g., left atrial size, NYHA class) and treatment outcomes, accounting for confounders. Transthoracic echocardiography was performed using a GE Vivid E95 system with a 4Vc-D

Table 1 – Patient characteristics

Indicator		Data
Age, years		63 ± 9
Gender	women (%)	37 (53%)
	men (%)	32 (47%)
Dimensions of the left atrium, mm		52 ± 6
Ejection fraction, %		51 ± 8.4%
Cross-clamp time, min		138 ± 43 min
HF according to NYHA III		34 (49%)

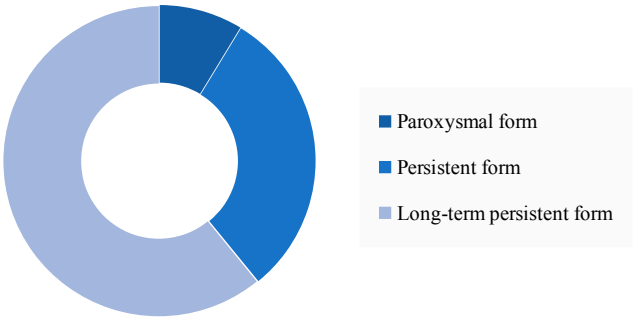

Fig. 1 – Percentage of patients according to the form of atrial fibrillation.

transducer, measuring left atrial diameter (via 2D-guided linear LA measurement) and ejection fraction. Heart failure symptoms were classified using the NYHA functional scale based on clinical evaluation. Outcomes included sinus rhythm restoration, NYHA class improvement, and recurrence rates of atrial fibrillation or flutter. These were assessed during follow-up visits at 1-, 3-, and 6-months post-surgery, ensuring a comprehensive evaluation of treatment effectiveness.

Figure 1 shows the breakdown of patients by arrhythmia type before the surgical ablation procedure. Among all patients, 6 had paroxysmal atrial fibrillation, 21 had persistent atrial fibrillation, and 42 had long-standing atrial fibrillation.

The inclusion criteria for the study required patients to have a confirmed diagnosis of atrial fibrillation (paroxysmal, persistent, or long-standing), be classified as NYHA functional class I–III (mild to moderate symptoms of heart failure without severe limitations on physical activity), demonstrate clear consciousness as assessed using the Glasgow Coma Scale with a minimum score of 15 (indicating full alertness and orientation), and provide voluntary informed consent to participate. Exclusion criteria encompassed the presence of decompensated neurological or cognitive disorders, defined as conditions causing significant functional impairment such as advanced dementia or uncontrolled epilepsy. Psychiatric illnesses diagnosed by a specialist, uncontrolled pathological conditions such as severe infections or metabolic disorders, NYHA class IV heart failure, or stage 3 heart failure (indicating severe functional limitation and end-stage disease) also led to exclusion from the study.

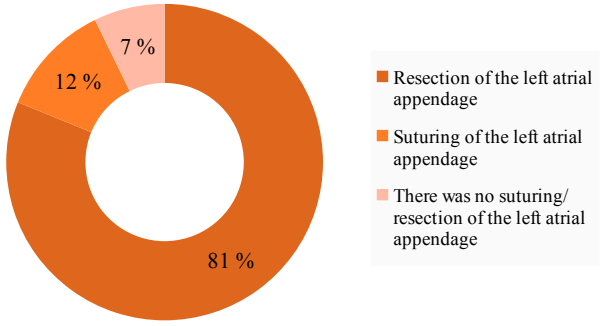

Fig. 2 – Percentage of left atrial annulus interventions.

Table 2 – Surgeries in conjunction with which left atrial surgical ablation of atrial fibrillation was performed

Operations	No. of procedures	Percentage, %
Mitral valve procedure (± tricuspid procedure)	34	49.3
CABG + mitral valve procedure (± tricuspide procedure)	16	23.3
Aortic valve procedure and mitral valve procedure (± tricuspid procedure)	12	17.4
CABG	1	1.4
CHD (cor triatriatum)	1	1.4
Aortic valve procedure (± tricuspid procedure)	3	4.3
ASD repair (± tricuspid procedure)	2	2.9
Total	69	100

All patients underwent left atrial radiofrequency surgical ablation of atrial fibrillation and concomitant operations, depending on the type of concomitant pathology, under general anaesthesia and with a cardiopulmonary bypass. The average time of surgery was 4.5 hours. **Table 2** shows the distribution of patients into groups according to the type of surgical treatment.

In the course of surgical interventions, the left atrial appendage was resected or sutured (**Fig. 2**).

Prior to the study, all patients signed a voluntary informed consent to surgery and the processing of their personal data for participation in the study.

In order to study the risk factors for AF, its prevalence, mechanisms of development and treatment methods, a search for relevant information in PubMed and Google Scholar databases published in 2018-2024 was conducted. A combined set of keywords was used: "atrial fibrillation", "surgical ablation", "radiofrequency ablation", "left atrial ablation". The received publications were carefully studied and selected by title, abstract, relevance of the topic and appropriate level of evidence for case studies. The present study includes papers that fully met the selected criteria. In total, 30 papers are cited in the presented research.

Results

Results of the surgical intervention

All patients underwent left atrial radiofrequency surgical ablation of atrial fibrillation, surgical treatment of coronary heart disease, and valve pathology. The choice of surgical intervention depended on the presence of concomitant pathologies, complications, and the age of the patients. The study revealed that after the left atrial radiofrequency surgical ablation of atrial fibrillation, 45 patients (65% of all patients) had a sinus node as the rhythm driver (**Fig. 3**). Rhythm disturbance in the form of atrial fibrillation remained in 18 patients, atrial flutter was observed in 4 patients, and left atrial flutter was observed in 2 patients.

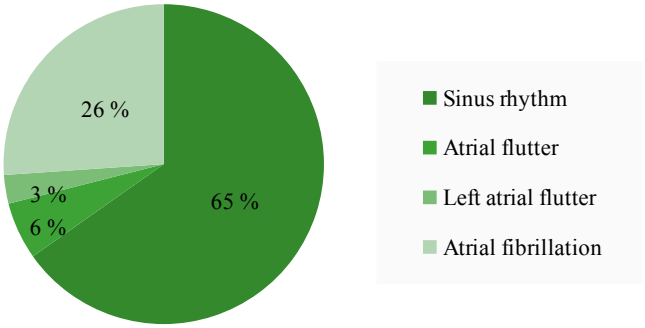

Fig. 3 – Percentage distribution of left atrial surgical ablation results.

After analysing the data obtained, it was concluded that radiofrequency ablation of the left atrium alone was conditionally successful, primarily in patients with shorter AF duration and smaller left atrial size. At the same time, the effectiveness of radiofrequency ablation was lower in patients with traditional predictors of failure, namely, age 75 years or older, left atrial size of 5 cm or more, atrial fibrillation duration of more than 5 years, and non-paroxysmal AF. Among the study participants, almost 61% (42 patients) had long-standing atrial fibrillation and a mean left atrial size of 5.2 ± 0.6 cm, which significantly worsened the results of surgical treatment. Therefore, for patients with traditional predictors of surgical ablation failure, it is necessary to implement the classical Cox-Maze IV procedure and cryoablation as an independent technique.

Atrial fibrillation: aetiology, mechanism of development, and classification

Atrial fibrillation is a supraventricular tachyarrhythmia based on discoordinated electrical activation of the atria and impaired contractile function of the heart. On an electrocardiogram, this pathology is manifested by irregular RR intervals, the absence of clear repeated P waves and irregular atrial activation. The main risk factors (RF) that cannot be influenced include: old age, male gender, and Caucasian race. At the same time there are many more factors that depend on the individual: physical activity level, weight control, diabetes mellitus, high blood pressure.

Age is a major risk factor for AF.[13] This is because people over 65–70 years of age have chronic subclinical inflammation, increased reactive oxygen species concentration, endothelial dysfunction, increased collagen breakdown, and vascular ageing at all levels. A quarter of AF cases is associated with high blood pressure. This is due to the fact that chronically high blood pressure causes the left atrium (LA) and left ventricle (LV) to be restructured, and contributes to profibrotic changes in the heart. The risk of developing AF among people with obstructive sleep apnoea increases fourfold.[14] This is due to the repeated cessation of ventilation caused by the collapse of the upper airway, which leads to hypoxia, increased intrathoracic pressure, hyperactivity of the autonomic nervous system of the heart, systemic inflammation, and oxidative stress.

Atrial stretch caused by fluctuations in negative chest pressure during apnoea, which contributes to further chronic structural remodelling, as well as acute dysregulation of calcium handling and electrical function. Type 2 diabetes mellitus is associated with a one-and-a-half-fold increase in the risk of AF. In this disease, oxidative stress and inflammation are the main factors of mitochondrial dysfunction and DNA damage, which creates the basis for the formation of AF. Obesity causes electroanatomical remodelling, increases neurohormonal activation, which modulates LA enlargement, and electrical instability; in obesity, the thickness of epicardial fat increases, which worsens atrial electrophysiology. A number of comorbidities also increase the risk of AF. For example, in patients with HF, the development of AF is 4–6 times higher; albuminuria, mild renal impairment, and reduced renal function are associated with a higher incidence of AF (with an GFR <30 ml/min/1,73 m^2, the risk was 60% higher).

One of the main mechanisms of AF development is fibrosis, due to its ability to electrically and structurally remodel heart muscle tissue.[15] Fibrosis is divided into: reparative fibrosis (replacement of necrotic cells) and interstitial fibrosis (excessive deposition of pathological proteins without the need to replace damaged cells). These changes are based on the excessive accumulation of extracellular matrix proteins in the interstitium of the inner layer of the heart due to a significant proliferation of fibroblasts in response to pathology. Under normal conditions, fibroblasts are responsible for maintaining the normal structure of the heart.[16] With the development of the fibrosis process, fibroblasts turn into myofibroblasts, which contribute to a decrease in myocardial conduction and arrhythmogenic effect.[2] This is due to the fact that an increase in the number of myofibroblasts disrupts the continuity of myocardial bundles and makes it impossible to form gap junctions between cardiomyocytes. Consequently, conduction abnormalities and the formation of unidirectional conduction blocks occur.

The inflammatory process is also a link in the pathogenesis of AF. C-reactive protein levels are associated with recurrence after cardioversion, while the restoration of sinus rhythm contributed to a decrease in this marker. During inflammation, angiotensin II promotes the formation of proinflammatory cytokines and causes cardiac tissue remodelling through the activation of MAPK mediators AngII/AT1R and the subsequent expression of profibrotic TGFβ1, which promotes fibroblast differentiation. The effect of angiotensin II is associated with impaired calcium handling and subsequent electrical remodelling of the atria.[17,18]

Atrial fibrillation is classified into:

1. Paroxysmal form (episodes stop within a week as a result of treatment or on their own, with attacks recurring with an uncertain frequency).
2. Persistent form (in the presence of continuous episodes lasting more than a week that do not stop).
3. Long-term persistent form (continuous episodes lasting more than a year).
4. Permanent form (continuous episodes, with no attempts to restore or maintain normal sinus rhythm).

5. Non-valvular form (symptoms occur in the absence of rheumatic heart disease or an artificial heart valve).[18,19]

Non-invasive diagnostic methods for predicting af recurrence after surgical ablation

Echocardiography is a non-invasive, painless, fast, and affordable examination method. This method allows determining the diameter and volume of the LA, left atrial appendage, and LA ejection fraction, which correlate with the risk of AF recurrence. Epicardial adipose tissue performs endocrine and inflammatory functions; increased thickness of this tissue, measured by ultrasound, is associated with recurrent AF. Speckle tracking echocardiography is a new effective noninvasive echocardiographic technique that allows detecting LA stretch during the filling and contraction phases and, on this basis, predicts the risk of recurrent AF. Lower peak values of LA longitudinal strain measured by this technique were independent predictors of AF recurrence after radiofrequency ablation.

Cardiac CT is a non-invasive method for assessing the anatomy of the left atrium and an accurate tool for diagnosing left atrial appendage. A contrast defect of the left atrial appendage detected on preoperative CT images was a predictor of AF recurrence. This is because contrast defects are caused by a decrease in function. In addition, the volume of atrial septal fat, pericardial fat volume, and pericoronary adipose tissue weakening detected during CT diagnostics are directly related to an increased risk of AF recurrence. Magnetic resonance imaging (MRI) determines the volume of the left and right atria, biventricular volume, LA sphericity, dilation index, LA ejection fraction, intraatrial dyssynchrony during sinus rhythm, total relative length of the ablation line, fibrosis, which is used to determine the risk of AF recurrence. LA fibrosis determined on MRI images using gadolinium contrast material shows promising efficacy in predicting the risk of recurrence after ablation in patients with.[20]

Surgical treatment of atrial fibrillation

Catheter ablation is the first line of treatment for paroxysmal atrial fibrillation. This method is more effective than antiarrhythmic drugs in terms of efficacy and improved survival in patients with AF and HF. The ablation catheter leads to the establishment of sinus rhythm in patients. However, most patients require several ablation procedures to restore a stable sinus rhythm.[12,17] New endocardial catheters provide favourable results in persistent AF. In 54.8% of patients with a mean duration of persistent AF of 7 months, atrial arrhythmias were absent 12 months after cryoballoon ablation.[19]

There are different ablation techniques: bi-atrial ablation, Cox IV method, left atrial ablation, and pulmonary vein isolation. These techniques are relatively minimally invasive, reduce the time of surgery, and reduce the risks of early mortality and complications. The rate of early recurrence after radiofrequency ablation is 20-40%. This is due to early inflammation, incomplete scar formation, and reconnection of the pulmonary vein. Compared to radiofrequency ablation, the cryoballoon technique is more effective. Very late recurrences, which occur a year or more after the operation, are described in 9% of patients. They are diagnosed with elevated blood pressure and low-density lipids. Factors that contribute to recurrence are overweight, metabolic syndrome, and a large amount of pericardial fat. Obstructive sleep apnoea is an accurate predictor of AF recurrence, as it promotes atrial remodelling in patients.[17]

Not all patients with AF need coronary artery bypass grafting or valve surgery or replacement.[21] In such cases, autonomous Cox's labyrinth operations are performed through sternotomy or right thoracotomy. Surgical ablation is performed without stopping the heart, so no atriotomy or endocardial incision is required. The effectiveness of epicardial surgical video thoracoscopic ablation is higher than endocardial catheter ablation. Cox IV labyrinth surgery demonstrates better results in persistent and long-term persistent AF. In its original form, this technique was based on cutting and stitching using numerous incisions and stitching to create a labyrinth of transmural conduction blocks. However, such surgical intervention was not effective enough and as a result of many years of modifications, the Cox-Maze IV technique was developed. It is based on only one incision in the left atrium and two incisions in the right atrium. The hybrid epicardial and endocardial ablation technique was developed to create a minimally invasive method of surgery without cardiac arrest, while combining the advantages of existing surgical and electrophysiological approaches.

There are two approaches to hybrid ablation, which differ in terms of pericardial access and epicardial ablation technique. The first method of hybrid ablation provides access to the posterior part of the left atrium thoracoscopically, and the second – endoscopically. Thoracoscopic ablation of atrial fibrillation in combination with hybrid AF ablation is an effective treatment for patients with symptomatic, drug-resistant paroxysmal or persistent AF. When using the standard hybrid ablation technique, the gentlest bilateral thoracoscopic ablation of the epicardium is performed with transvenous endocardial electrophysiological testing and correction of incomplete epicardial lesions. This treatment significantly reduces the risk of AF recurrence (in paroxysmal AF, the recurrence rate is 20%, and in persistent AF, 21% within 3 years). The main complications in the early postoperative period encompass: perioperative major complications included: bleeding, with the need for repeated surgery, cardiac tamponade, myocardial infarction, and pneumothorax.[18,22,23] Hybrid convergent surgery is performed under endoscopic visualization followed by catheter ablation. This technique is the least invasive hybrid surgery for AF.

Prevention of atrial fibrillation and cardiovascular diseases

Regular physical activity reduces the risk of AF by 2 mechanisms: directly by reducing the likelihood of AF, and indirectly by controlling body weight and blood pressure. 500 MET-min/week (metabolic equivalent of a minute's work per week) of regular exercise is recommended. Patients with already diagnosed AF are also recommended to exercise. It reduces the risk of ischaemic and haemorrhagic strokes and diseases of the white matter of the brain. Moderate-intensity exercise has been shown to

reduce symptoms and improve the functional capacity of the cardiovascular and respiratory systems.[23–26]

The choice of diet has a significant impact on the health of the cardiovascular system. A properly selected dietary pattern normalizes body weight, blood pressure and cholesterol levels. The anti-inflammatory properties of food can reduce chronic inflammation, reducing the risk of AF. For example, such components of the Mediterranean diet as lean fish and olive oil reduce oxidative stress, which is the primary and secondary prevention of AF. A plant-based diet has an anti-inflammatory effect, and its high fibre content improves the functioning of the gastrointestinal and cardiovascular systems.[27] Regular consumption of nuts reduces the level of low-density lipoprotein by 10–12%. Antioxidants and polyphenols contained in fruits and vegetables enhance the growth of *Bacteroides*, reducing inflammation and oxidative stress.[28] Cruciferous vegetables (e.g., cabbage and broccoli) promote the conversion of trimethylamine to trimethylamine-N-oxide, which reduces ventricular remodelling, improves hemodynamic parameters, and reduces the risk of atrial fibrillation.[29–31]

Patients with heart disease should avoid ultra-processed foods, as they increase inflammation and dyslipidaemia. Caffeine and methylxanthine contained in coffee and tea have a neurohormonal effect and affect the sympathetic nervous system. Caffeine causes a decrease in atrial muscle contractility and a decrease in the activity of the sinoatrial node. Alcohol exposure causes oxidative stress, release of fatty acids into the blood plasma, and reduction of atrial action potential, which leads to the development of AF. Chronic alcohol intake causes electrical disturbances, increased sympathetic tone, decreased sodium channel expression, and the development of hypertension and cardiomyopathy. At the same time, a small amount of alcohol <15 g/day for women and <30 g/day for men has a protective effect against coronary diseases. Resveratrol contained in red wine has antioxidant properties. It is necessary to exclude tobacco smoking. Daily poisoning with nicotine from cigarettes causes a violation of ionic conduction in atrial myocytes. This slows down ventricular repolarization and prolongs the refractory period by blocking the flow of K ions. Smoking increases fibrosis in the heart tissue, increases blood pressure and heart rate, increases the systemic release of catecholamines and promotes coronary vasospasm, which leads to myocardial ischaemia.[32,33] Thus, for the normal functioning of the cardiovascular system, it is important to avoid ultra-processed foods, giving preference to fresh vegetables and fruits, regularly devote time to physical activity and monitor blood pressure.

Discussion

As a result of the study, 34 patients, which is almost half of all patients, underwent mitral valve surgery with/without tricuspid valve surgery, and 16 patients (23.3%) underwent mitral valve surgery with/without tricuspid valve surgery with coronary artery bypass grafting. Aortic valve surgery in combination with mitral valve surgery with/without tricuspid valve surgery was performed in 12 patients (17.4%). Aortic valve surgery with/without tricuspid valve surgery was performed in 3 patients (4.3%). Atrial septal defect repair with/without tricuspid valve surgery was performed in 2 patients (4.3%). One surgery was performed due to congenital heart disease and one isolated coronary artery bypass grafting. The most favourable treatment results were found in patients with shorter AF duration and smaller left atrial size.

The study by Malagoli et al.[34] also indicated that structural remodelling of the left atrium and an increase in its volume positively correlated with the onset of AF and was one of the predictors of AF recurrence after pulmonary vein isolation. Zolotarova et al.[35] found that the duration of the QT interval before radiofrequency ablation and its prolongation after surgery were independent predictors of atrial fibrillation recurrence; the diameter of the left atrium before ablation was a highly sensitive predictor in patients with chronic heart failure with preserved LV ejection fraction. Patients with normal LA size but a reduced left atrial ejection fraction have more frequent recurrence after ablation.[36] Cardiac endothelin-1 concentration correlates with increased left atrial size, promoting myocyte hypertrophy and myocardial interstitial fibrosis. Atrial fibrosis causes a slowing of conduction and changes in dynamic repolarization. Khan et al.[37] found that the decrease in LA volume due to ablation was associated with the formation of a postoperative scar directly on the atrium. This was described in all patients, regardless of the existing heart rhythm. Taking into account the left ventricular diastolic function, it is possible to predict the recurrence of AF after ablation. This is because LA function is directly related to normal left ventricular filling. At the same time, the assessment of LA function by visualization of its deformities is more sensitive than the measurement of conventional LV filling parameters to determine the presence of LV diastolic dysfunction.

Scientists Tian et al.[38] noted that the volume of the LA annulus is an important predictor of atrial fibrillation recurrence after radiofrequency ablation. Patients who had an LA annulus volume of more than 25 ml were diagnosed with recurrent AF. The LA annulus is involved in the regulation of heart rate and fluid balance through its expandable reservoir function and the ability to secrete atrial natriuretic peptides and sensitive stretch receptors. The volume of the left atrial annulus is a reliable parameter for determining the function and structure of the left atrium in the early stages of AF.[39] In this study, during surgical interventions, 81% of patients underwent resection of the left atrial appendage, and 12% underwent ligation.

According to the results of the study, it is recommended to implement the classic Cox-Maze IV procedure for patients with traditional predictors of surgical ablation failure. Khiabani et al.[40] noted that this surgical intervention is highly effective in restoring sinus rhythm, and reduces surgical morbidity and mortality. The technique is equally successful in patients undergoing ablation for AF alone, AF in combination with concomitant cardiac surgery, including coronary artery bypass grafting, mitral valve, aortic valve, and septal myectomy procedures. Cox-Maze IV demonstrates approximately the same outcomes for patients with both paroxysmal and non-paroxysmal

(persistent and long-standing) forms of AF. MacGregor et al.[41] also described the predictors of the first recurrence of AF after Cox-Maze IV surgery: older age, peripheral vascular disease, non-paroxysmal AF, enlarged left atrium, and absence of sinus rhythm at the time of discharge from the hospital increased the risk of the first recurrence within 10 years of follow-up. At the same time, the researchers determined that obesity did not adversely affect the short-term and long-term results of Cox-Maze IV, meaning that increased BMI is not a predictor of AF recurrence in this case.

The present study identified risk factors for AF, including overweight, hypertension, and smoking, while also highlighting the significant impact of psychological conditions. Ren et al.[4] noted that anxiety, depression, and mental disorders increase the risk of AF by more than five times. Patients with a history of AF spanning 5–2 years were found to have higher levels of depression, with the prevalence of depression in AF patients ranging from 40% to 43%. Additionally, Ren et al. observed that an increased left atrial diameter is associated with a higher likelihood of recurrent AF one year after radiofrequency ablation, emphasizing the multifactorial nature of AF progression and recurrence. Patients with persistent AF had more severe manifestations of depression compared to patients with paroxysmal AF. Older patients with AF are more likely to suffer from depression and anxiety. This is partly explained by physical disorders, unhealthy lifestyle, and cognitive impairment. Women have higher rates of depressive disorders and sleep disturbances than men, regardless of the type of AF.[42] The greater susceptibility of women to mental disorders can be explained by sex differences, genetic factors, differences in daily life or health behaviour. At the same time, 50–70% of patients with chronic illnesses have undiagnosed depression (due to a frequent lack of awareness of symptoms, unclear clinical picture, and unwillingness to admit the problem). Also, high levels of depression were observed in patients who were not sufficiently informed about their health status and in those who had poor relationships with medical staff.

Patients with AF who receive accurate and detailed information about their condition often report fewer symptoms, improved disease management, and reduced emotional stress. This highlights the importance of patient education as a component of comprehensive AF care. Anxiety and depressive disorders play a significant role in the progression and recurrence of AF by activating the renin-angiotensin-aldosterone system, which leads to fibrosis, delayed atrial conduction, increased atrial pressure, and electrophysiological remodelling. These effects are further compounded by chronic depressive states, which elevate inflammatory cytokines, reactive oxygen species, and catecholamines, contributing to nervous system dysfunction and creating conditions favourable for AF recurrence. Research has shown that the presence of even mild depressive symptoms significantly increases the likelihood of AF recurrence following surgical or medical interventions. This association underscores the need for healthcare providers to recognize and address mental health as a critical factor in AF management. Routine screening for anxiety and depression should be integrated into standard care protocols, particularly for patients undergoing surgical treatment or those with advanced forms of AF.

Incorporating psychological support measures, such as stress management programs, counselling, or appropriate pharmacological interventions, could enhance treatment outcomes and improve patients' overall quality of life. This multidisciplinary approach aligns with current evidence, suggesting that addressing mental health factors not only reduces recurrence rates but also contributes to better long-term management of AF. Expanding clinical guidelines to include mental health support for AF patients, especially those with comorbid cardiac conditions, could lead to more effective and patient-centred care. Such efforts are essential to improving outcomes and reducing the burden of AF on both patients and healthcare systems.

Limitations

The limitations of this experiment were a small sample of study participants, a single-centre study, and the lack of randomization. Therefore, it is necessary to conduct further large-scale randomized clinical trials to determine the most effective methods of surgical treatment of atrial fibrillation, taking into account predictors of failure.

Conclusions

It was found that after the procedure of left atrial radiofrequency surgical ablation of atrial fibrillation, the sinus node served as the rhythm driver in 45 patients (65% of all). In 18 patients (26%), rhythm disturbances in the form of atrial fibrillation persisted, while 4 patients (6%) had atrial flutter, and 2 patients (3%) had left atrial flutter. Notably, 61% (42 patients) had a long-term persistent form of atrial fibrillation and an average left atrial size of 5.2 ± 0.6 cm, which significantly affected the outcomes of surgical treatment. The efficacy of radiofrequency ablation was lower in patients with traditional predictors of failure, such as being over 70 years of age, left atrial size of 5 cm or more, atrial fibrillation duration of more than 5 years, and persistent or long-standing AF. These findings emphasize the need for alternative approaches in patients with these predictors of failure. For such cases, the implementation of the classic Cox-Maze IV procedure or cryoablation as an independent technique is recommended to improve treatment success. Beyond surgical interventions, preventive measures play a crucial role in managing atrial fibrillation and reducing its recurrence. Adopting a healthy lifestyle that includes daily physical activity of moderate intensity, a balanced diet rich in fresh vegetables and fruits, lean meat and fish, along with controlling alcohol consumption, blood pressure, and body weight, and avoiding smoking, can significantly contribute to the prevention and better management of AF. By integrating these preventive strategies with tailored surgical approaches for high-risk patients, clinical outcomes can be optimized, providing a more comprehensive and patient-centred management of atrial fibrillation.

Conflict of interest
The authors declare none.

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Ethical statement and consent to participate
All procedures performed in the study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. Prior to the study, all patients signed a voluntary informed consent for participation in the study.

Consent for publication
All patients signed a voluntary informed consent to the processing of their personal data for the study.

Author contributions statement
O.Sh-D.: Conceptualization, Methodology, Supervision, Writing – Original Draft; S.V.: Conceptualization, Data Curation, Investigation, Writing – Review & Editing; P.Sh.-D.: Methodology, Formal Analysis, Writing – Original Draft; I.Z.: Investigation, Visualization, Resources, Writing – Review & Editing. N.R.: Formal Analysis, Project Administration, Validation, Writing – Review & Editing.

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